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ABUNDANCE AND LIFE HISTORY OF SHAD ST. JOHNS RIVER, FLORIDA

By Charles H. Walburg

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ABSTRACT

A method of determining the size and spawning escapement of the shad (*Alosa sapidissima*) population of the St. Johns River, Florida, is presented and population parameters are given for each year 1953 to 1958. Scientific management of the shad population in this river to obtain optimum yields is not possible at this time because factors affecting the size of run are unknown. When data on population size have been obtained for an additional number of years, studies can proceed to determine factors affecting abundance.

Examination of 3,129 scale samples revealed that the majority of shad caught in the St. Johns River are 4 years of age. From the absence of spawning marks on the scales and from other evidence it is apparent that the shad die after their initial spawning run. Females produce 277,000 to 659,000 eggs, and a direct relation exists between the number of eggs produced and the age, length, and weight of the fish. The spawning season extends from late February to mid-April, during which time water temperatures range from 60° to 75° F.

ABUNDANCE AND LIFE HISTORY OF SHAD, ST. JOHNS RIVER, FLORIDA

By CHARLES H. WALBURG, *Fishery Research Biologist*
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During the first half of the twentieth century the commercial catch of American shad, *Alosa sapidissima*, along the Atlantic coast of the United States declined from 48 million pounds to 8 million—a reduction of 83 percent. The fishing industry, through the Atlantic States Marine Fisheries Commission, requested the Federal Government to make a study of the fishery. In 1949, the Congress, in Public Law No. 249, authorized the Fish and Wildlife Service, United States Department of the Interior, to make a comprehensive investigation of the Atlantic coast shad fishery. The objectives of this study, which began in 1950, were (1) to discover causes for decline of the fishery, (2) to determine conditions favoring its recovery, and (3) to provide information for scientific management of the fishery to obtain maximum continuing yields.

The American shad is the largest member of the herring family (Clupeidae) in North American waters. Its range on the Atlantic coast is from the St. Johns River in Florida to the St. Lawrence River in Canada. The shad is anadromous, spending most of its life in the sea, but ascending coastal rivers to spawn. The spawning migration begins as early as November in Florida and as late as June in Canada. Time of spawning migration is at least partially governed by water temperature since few shad enter rivers at temperatures below 40° F. (Talbot 1954; Massmann and Pacheco, 1957). Shad spawn in the fresh-water part of rivers generally at water temperatures between 53° and 68° F. The females deposit their eggs in the open water where fertilization takes place. The number of eggs produced per female ranges from 116,000 to 616,000 (Lehman 1953; Davis 1957). After absorbing water, the eggs sink to the river bottom but are carried by the current. Hatching occurs in 6 to 8 days, depending on water temperature (Leim 1924).

Talbot and Sykes (1958), using 19 years' tagging data, made an extensive study of shad migrations. According to these authors, shad native to streams north of Cape Hatteras, N.C., that survive spawning, migrate to sea and the following year return to spawn again provided they survive natural and fishing mortalities. Those fish native to streams south of Cape Hatteras die after spawning. The young remain in the rivers until fall, at which time they are 3 to 6 inches in length, and then enter the ocean. They remain in the ocean from 3 to 5 years and at sexual maturity most of them return to the streams of their birth to complete the cycle.

Talbot and Sykes further state that shad from all Atlantic coast rivers spend the summer and fall months in the Gulf of Maine. The fish spend the winter in the Middle Atlantic area, probably in deep water, and with the approach of spring they migrate inshore, destined for their native rivers. This same annual migration is made by the juveniles except they do not enter the rivers until sexually mature.

The shad fishery of the St. Johns River in Florida was first investigated during the winter of 1952–53. Each year from that time through 1958 catch and effort data have been obtained from the commercial fishery and estimated catch data have been obtained from the sport fishery. During the 1957–58 run, the fishery was further investigated to determine fishing rate and size of run for each year 1953 through 1958 and to obtain basic life-history information.

The staff of the Bureau of Commercial Fisheries, Biological Laboratory, Beaufort, N.C., helped with the field studies and reviewed this manuscript. Appreciation is also expressed to

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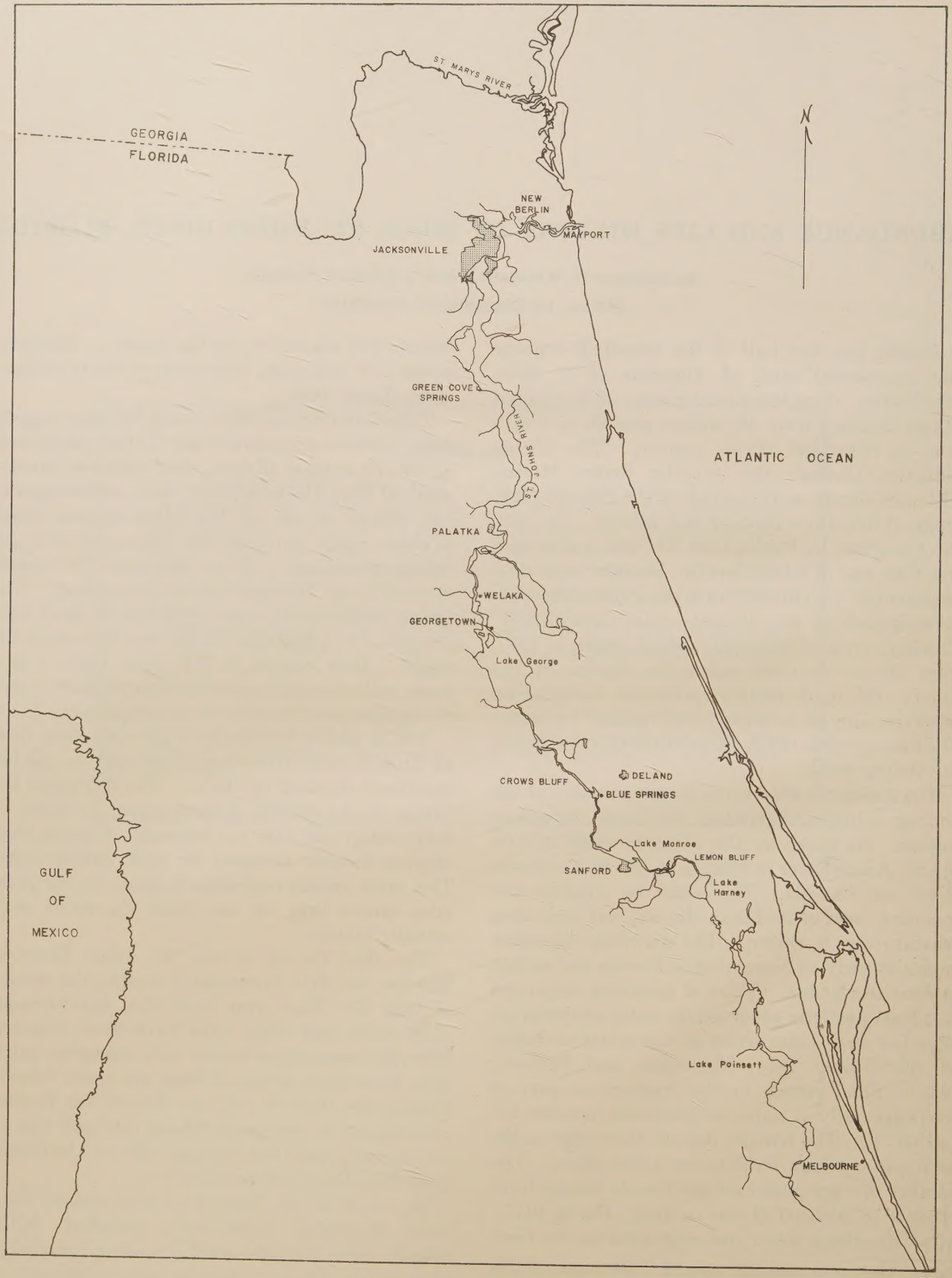

FIGURE 1.—St. Johns River, Florida.

the shad fishermen, fish dealers, and sport-camp operators on the St. Johns River, who cooperated in this study.

THE RIVER AND THE SHAD FISHERIES

The St. Johns River originates in a grassy plain section of Florida about 50 miles north of Lake Okeechobee and 15 miles inland from the State's east coast. It flows north through a chain of lakes for approximately 260 miles to Jacksonville and then turns east and flows 26 miles before emptying into the Atlantic Ocean at Mayport (fig. 1). The St. Johns River differs from other large rivers along the Atlantic coast of the United States in that it flows northward, whereas the other rivers originate farther inland and flow in a southerly direction before entering the ocean.

In its headwaters the St. Johns is not a clearly defined river, since it is shallow, winding, and diffused. In its northward meandering through shallow lakes it creates many diverse channels until Lake Harney is reached. From here to its mouth the river is deeper and has a distinct channel suitable for navigation. Lake George, the only sizable lake existing between the river mouth and Lake Monroe, lies 25 miles south of Palatka and is the approximate head of tidal influence.

In recent years the commercial fishery has operated in widely separated and relatively short stretches of the river. At the mouth, anchor gill nets are fished both north and south of jetties which extend out into the ocean about 1 mile. During the 1958 season, 5,700 linear yards of anchored gill net, 30 to 35 meshes deep and with a stretched-mesh size of 5 to 5¼ inches, were used. In the vicinity of Jacksonville, 26 miles up the river, drift gill nets are used. The three drift gill nets fished in 1958 averaged 100 yards in length and 35 meshes in depth with a stretched-mesh size ranging from 4 to 5¼ inches.

The 55-mile section of the river from Jacksonville to Palatka is broad and composed of numerous flats. No shad fishing is done in this area. Between Palatka and Welaka, a distance of about 20 miles, drift gill nets and haul seines, locally termed shad nets, are used. In 1958 three gill-net operators in the vicinity of Palatka fished 580 linear yards of net. The depth of these nets ranged from 25 to 50 meshes and their stretched-mesh size was 5¼ inches. Nine haul seines totaling 3,240 yards in length were fished between the Palatka gill-net area and Welaka. These nets ranged in length from 300 to 380 yards, in depth from 20 to 30 feet, and in stretched-mesh size from 2 to 4 inches. No commercial netting was done upstream from Welaka in 1958.

In years previous to 1953, haul seines were fished in the vicinity of Lemon Bluff; since that time, however, commercial shad fishing has been prohibited upstream from the Lake George bar. The legal commercial shad fishing season in the St. Johns River is from November 15 until March 1, but the season can be extended, as occurred in 1958, to March 15 at the discretion of the State Board of Conservation.

Sport fishing for shad is conducted between Lakes Monroe and Harney. There are no legal restrictions on the taking of this species with sport tackle, but there is a creel limit of 15 shad a day.

THE COMMERCIAL FISHERY

According to historical accounts, the first shad fishery in the St. Johns River began in the middle of the nineteenth century. McDonald (1887) quotes R. E. Earll's account of the fishery—

> Shad were first caught at Mayport by Charles Waterhouse, of Connecticut, in 1858. He had previously fished in the Savannah, but abandoned it on account of poor results. At Jacksonville gill nets were first used in the shad fisheries in 1868. At Palatka, C. B. Smith, of Connecticut, was the first to establish a shad fishery. He began the work in 1872, and it was not until 1877 that a second fishery was started. In the year 1873, 94,000 shad were caught at New Berlin with thirty nets (an average of 3,133 to the net). From 1865 to 1875 the average catch was 25,000 [1] to the net. The year 1876 was the most prolific season of all, when each net averaged a catch of 5,000. In 1875, at Palatka one net caught 11,000 shad, and in the same year it is said six nets took 55,000.

Dr. Charles Kock, in a letter to Mr. Earll from Jacksonville dated January 1874, says—

> From the bar at the mouth of the Saint Johns River up to Palatka, seventy-five to eighty nets are fished during the shad season. These nets are about 200 yards long and 10 feet deep (the mesh 1½ inches square), and are set in from 10 to 12 feet of water. In 1874 the product of the shad fisheries amounted to 250,000 shipped or consumed. The average price at Jacksonville, season of 1872–73, was 15 cents apiece.

From available records (table 1) a figure was constructed showing the commercial shad catch made in the St. Johns River for some years, 1880–1958 (fig. 2). These catches (except for

[1] Probably should be 2,500.

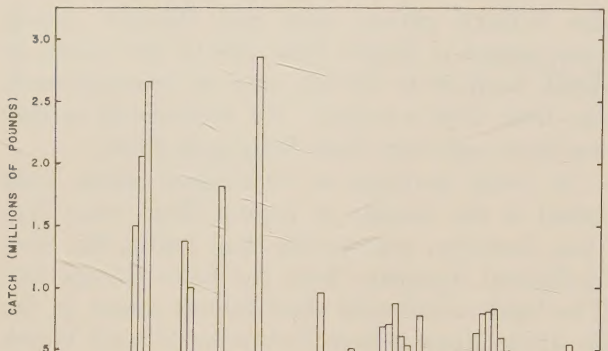

FIGURE 2.—The commercial catch of shad in the St. Johns River for various years, 1880–1958. (See table 1 for source of data. Catch for years 1880–1952 recorded on annual basis and for years 1953–58 on seasonal basis.)

years 1953–58) are recorded for the calendar year rather than for the fishing season. Each fishing season includes the latter part of one year and the early part of the next. Although catch data tabulated on an annual versus a seasonal basis are not strictly comparable, no serious error will result from their comparison here, since less than 20 percent of the seasonal catch is made during the months of November and December. According to data shown in table 1 and figure 2, the fishery reached a peak production of 2,833,000 pounds in 1908. After this time the catch declined drastically and since 1918 has fluctuated between 203,000 and 964,000 pounds. Except for the period 1953–58, no data are available concerning the amount of gear employed in landing these catches; therefore, it is impossible to say whether fluctuations in catch are attributable to varying fishing intensity, actual changes in shad abundance, or a combination of these factors.

TABLE 1.—*Commercial catch of shad for various years, 1880–1958, St. Johns River, Florida*

[In thousands of pounds. Statistics for 1880–1952 from Power (1958) except as noted; statistics for 1953–58 from this study]

Year	Catch	Year	Catch
1880	252	1939	254
1888	1,448	1940	344
1889	2,051	1941	[2] 256
1890	2,654	1942	[2] 323
1896	[1] 1,375	1943	[2] 666
1897	1,011	1944	[2] 811
1902	1,819	1945	842
1908	2,833	1946	[2] 837
1918	964	1947	[2] 625
1923	503	1948	[2] 515
1927	348	1949	[2] 284
1928	691	1950	298
1929	701	1951	336
1930	880	1952	203
1931	621	1953	280
1932	546	1954	343
1934	782	1955	434
1936	282	1956	293
1937	288	1957	261
1938	229	1958	552

[1] The 1896 catch in fish (Stevenson 1899) converted to pounds by factor of 3.0.
[2] Data gathered by Florida State Board of Conservation.

Population Studies, 1953

The shad fishery in the St. Johns River was first investigated by the Fish and Wildlife Service during the 1952–53 season. To avoid confusion, the 1952–53 shad season will be termed the 1953 season, and the 1953–54 shad season the 1954 season, and so on. The purpose of the 1953 study was to determine the total catch, total effort, population size, and spawning escapement. These base-year estimates were to be used with catch and effort statistics collected in subsequent years to determine population parameters for each year in which such data were obtained.

In 1953, catch and effort data were obtained from fish dealers who supplied a daily record of the catch by each fisherman. Tagging studies were conducted from the drift gill-net fishery at Jacksonville and from the haul-seine fishery in the Welaka-Palatka area. An attempt was made to tag from the anchor gill-net fishery at the mouth of the river, but this was unsuccessful because live fish suitable for release could not be obtained. At Jacksonville we were unable to obtain a sufficient number of fish to tag, and in the Welaka-Palatka region an unknown portion of the run had passed through the area before tagging was begun. In addition, some of the fish tagged in the latter area were in poor condition because of higher than normal water temperatures during the winter of 1952–53. Results of the tagging studies at both Jacksonville and in the Welaka-Palatka area were inconclusive and therefore not used for population estimation. Much information concerning the fishery was obtained, however, that was of value to the 1958 investigation.

Catch and Effort Statistics, 1953–58

Catch data have been obtained from the commercial fishery each year since our initial investigation. They were obtained from fish dealers in Mayport, Jacksonville, Palatka, Welaka, and Georgetown, Fla., who purchase all commercially caught shad taken in the St. Johns River (table 2). Effort data in net-days by months were obtained from the haul-seine fishery (table 3). A

TABLE 2.—*Commercial catch of shad, by fishing gear and area, St. Johns River, Florida, 1953–58*

[In thousands of pounds]

Year	Gill net		Haul seine	Total catch
	Mayport-Jacksonville	Palatka	Welaka-Palatka	
1953	60	19	201	280
1954	47	35	261	343
1955	36	17	381	434
1956	99	20	174	293
1957	71	8	182	261
1958	186	22	344	552

net-day is defined as a day during which a haul seine is used. Total effort is given as the number of net-days for all haul seines. Accurate catch and effort statistics are available from this fishery, since haul-seine operators keep a daily record of the catch made by each net. Comparable effort statistics for the gill-net fishery are not available.

TABLE 3.—*Net-days of fishing effort in the haul-seine shad fishery, St. Johns River, Florida, 1953–58*

Year	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1953		37	466	246	36	785
1954	11	47	234	278	46	616
1955	11	87	169	146	79	492
1956	6	60	108	99	30	303
1957	17	47	83	77		224
1958	24	64	140	123	75	426

Tagging Study, 1958

The catch and effort data given in tables 2 and 3 can be converted to estimates of population size for each year since 1953 provided an estimate of population size is available for 1 year (Ricker 1940). To obtain this parameter, a tagging and recovery program was conducted during the 1958 season.

Fish for tagging were obtained from the first haul seine encountered by the shad as they moved upstream to the spawning grounds. Tagging was done throughout the fishing season from November 26, 1957, to March 6, 1958. During this period, 950 shad were tagged with Petersen disk tags inserted directly below the origin of the dorsal fin. Care was taken that only vigorous fish were tagged to minimize mortality from the tagging operation. As an incentive for return of tags, a 50-cent reward was paid for each tag returned. Fishermen were contacted frequently to ensure as far as possible that all recaptured tags were recovered.

Ninety-seven tagged fish were recaptured by gill nets. The majority of these (88) were in the Palatka area; 7 were taken at Jacksonville and 2 at Mayport. Since the purpose of the tagging program was to determine the number of shad available to the haul-seine fishery, these 97 tags were subtracted from the total number tagged (950), leaving 853 available to this fishing gear. No tags were recaptured outside of the river; therefore, it is reasonable to assume that most, if not all, tagged fish that moved downstream after tagging eventually resumed their upstream migration to the spawning ground. This same pattern of movement has been assumed in other shad-tagging studies (Walburg 1955) and also in similar work with sockeye salmon, *Oncorhynchus nerka* (Thompson 1945).

During the fishing season, 108 tagged fish were included in the 344,000 pounds of shad which were taken by the haul seines. The estimated fishing rate of these nets was 108/853, or approximately 12.7 percent. Because of the small mesh size of the haul seines all shad encircled by this gear were considered captured regardless of whether they were tagged or untagged.

An estimate of the number of shad available to the haul-seine fishery was made using the following formula:

$$N=\frac{nt}{s}$$

where N=size of population available to haul seines, n=catch by haul seines (344,000 pounds), t=number of tagged fish available to capture (853), and s=number of tagged fish recaptured (108). The estimated number of shad available to haul seines was 2,717,000 pounds. In this study the ratio of the number of fish tagged to the number in the population was relatively low, and therefore confidence limits on the population estimate closely approximate a Poisson distribution. Using Chapman's (1948) equations 43 and 44, 95-percent confidence limits on the population estimates were 2,223,000 and 3,260,000 pounds.

Population Estimates, 1953–58

Before using the catch and effort data for the years 1953 to 1958 to estimate population size, several assumptions must be satisfied (Ricker 1940). They are as follows:

1. Fishing effort is uniform throughout the season.

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2. Efficiency, or fishing power, of the fishing gear remains constant within and between years.

3. Migration pattern of the shad is similar each year.

Assumption 1 is not completely satisfied for this fishery. Most fishing is done during January and February (table 3) because market conditions for shad are best during these months. Although fishing effort is not strictly constant over the period of annual exploitation, a similar pattern of fishing is followed each year, and any error introduced by nonuniform effort would therefore be negligible. Assumption 2 is satisfied since the haul seines have been fished by essentially the same crews, in the same manner, and in the same locations each year. Assumption 3 is satisfied since there is no reason to believe that the year-to-year migration pattern of the shad through the haul-seine fishing area is dissimilar even though variable river conditions may alter slightly the initial time of run or affect the speed of upriver migration. These latter effects should balance out over a period of years.

If these assumptions are considered satisfied, the size of the population available to the haul seines can be determined for each year that catch and effort data are available, using a method given by Talbot (1954). The formula is—

$$N=\frac{C}{1-q^n}$$

where N=number of shad available to haul seines; C=catch by haul seines; n=number of net-days fished by haul seines; and $q=1-p$, where p=the fishing power of a haul seine fished for one day, or the ability of a haul seine to catch a certain fraction of the fish present in 1 day's fishing. Using the 1958 data, the value of q was determined from the relation $q^n=\frac{E}{N}$ (Fredin 1954), where E=number of fish escaping the haul seine fishery. Total effort, fishing rate, catch, and estimated size of run available to the haul seines, 1953 through 1958, are given in table 4 as calculated.

To determine the total size of the shad run in the St. Johns River for the years 1953–58, the number of shad taken by gill nets was added to the number available to the haul seines. The commercial fishing rate for these years was determined by dividing the total commercial catch by the estimated total population in a given year. Escapement from the commercial fishery was determined by subtracting total catch from population size. Estimates of population size, commercial fishing rate, and commercial fishery escapement for years 1953–58 are shown in table 5.

TABLE 4.—*Calculated size of shad run available to haul-seine fishery, St. Johns River, Florida, 1953–58*

Year	Fishing effort (net-days)	Fishing rate (percent)	Catch (in thousands of pounds)	Estimated size of run (in thousands of pounds)
1953	785	22.1	201	910
1954	616	18.0	261	1,450
1955	492	14.5	381	2,628
1956	303	9.2	174	1,891
1957	224	6.9	182	2,638
1958	426	12.7	344	2,709

TABLE 5.—*Population statistics of shad runs, St. Johns River, Florida, 1953–58*

[In thousands of pounds]

Year	Gill-net catch	Size of run available to haul seines	Total population	Total commercial catch	Commercial fishing rate (percent)	Commercial fishery escapement
1953	79	910	989	280	28.3	709
1954	82	1,450	1,532	343	22.4	1,189
1955	53	2,628	2,681	434	16.2	2,247
1956	119	1,891	2,010	293	14.6	1,717
1957	79	2,638	2,717	261	9.6	2,456
1958	208	2,709	2,917	552	18.9	2,365

THE SPORT FISHERY

Sport fishing for shad by hook-and-line has become popular on the St. Johns River in recent years. The first shad was reported taken in this manner in 1942 in the Blue Springs area west of De Land (Snyder 1949). In recent years this fishery has shifted south, and now is pursued between the outlet or western end of Lake Monroe and the inlet or southern end of Lake Harney, a distance of 25 miles (fig. 1). Access to the sport-fishing area at present is limited to nine major landings. Seven of these are privately owned camps and two are public access areas. Sport fishing for shad on the St. Johns is done almost exclusively by trolling from boats with various types of small metal spoons and weighted jigs. The first shad are taken early in December and the fishery usually lasts into April. The best catches are made from the middle of January until the middle of March.

During the 1953 investigation, a limited survey was made to obtain an estimate of the sport catch. Analysis of these data revealed that the catch was

large, approaching one-third the size of the commercial catch. Since the sport catch was of such magnitude, information was obtained each year through 1957 from a major sport-fishing camp, on the number of shad boats rented and the number of shad caught. During the 1958 season, biologists conducted a creel census on the entire sport fishery to determine fishing effort and catch. These data were used together with that collected since 1953 to obtain an estimate of the sport catch for the years 1953–57.

Creel Census, 1958

A voluntary-reporting card system was used in the 1958 creel census. Before the start of the sport-fishing season the census program was explained to all sport-camp operators, and boxes to collect cards were erected at each of the nine major points where shad were landed. The boxes were mounted on posts with signs requesting fishermen to fill out a census card and drop it into the box. Each box had attached to it a supply of cards and a pencil. The census cards were numbered by location and contained space for fishermen to record date, number of persons in party, and number of male and female shad caught.

Biologists visited each landing as often as possible to ensure that a census card was filled out by each fishing party and deposited in the collection box. Effective coverage was possible because of the limited number of fishing areas. In the absence of a biologist, camp operators and boat handlers at each fish camp reminded fishermen to fill out a card. Biologists contacted the maximum number of fishermen during the time of heaviest fishing. In the morning each fish camp was visited and the survey was explained to fishing parties. Also, completed cards from the previous day's fishing were removed from the card box. In the afternoon the areas having large concentrations of fishermen were completely canvassed. Several of the camps are in close proximity and therefore could be checked by one man.

During the first 2 weeks of the survey, the creel census was conducted 7 days a week to acquaint as many fishermen as possible with the program. During the remainder of the study, the census was conducted 5 days a week including all weekends and holidays. Peak fishing activity occurred on weekends and holidays and low activity on Mondays and Tuesdays.

Publicity was given the creel census through newspaper, radio, and television facilities. Life-history and weekly-catch data were furnished these media, and they in turn publicized this information and requested sportsmen to cooperate in the survey.

The sport-fishing season extended over a period of 23 weeks, from November 25, 1957, through May 5, 1958, and during this period an estimated 65,246 shad were caught and kept. This figure was obtained by totaling the catch reported on census cards from all areas. It is probable that a few fishermen made no report of their catches; therefore, the sport-catch estimate is considered minimal. During the creel census, biologists personally checked the catch of fishermen in 2,436 boats who landed 21,462 shad, or 33 percent of the season's catch. The catch included a small, number of hickory shad (*Alosa mediocris*) which are identified as American shad by most fishermen and camp operators. The number of hickory shad caught each week was estimated from examination of the catch. Because these two species are not usually differentiated and the proportion of hickory shad in the catch was small (1,553 fish or 2.4 percent), we grouped them together in this study. The weekly catch of both species by sex is shown in table 6. Results of the census show that 13,025 fishermen fishing from 6,002 boats caught an average of 5 shad per fisherman-day, or 10.9 shad per boat-day. The

TABLE 6.—*Weekly sport-fishing catch of shad, by species and sex, based on return of census cards, St. Johns River, 1958*

Period	American shad			Hickory shad			Total both species
	Male	Female	Total	Male	Female	Total	
Nov. 25–Dec. 1	4	3	7				7
Dec. 2–Dec. 8	179	133	312				312
Dec. 9–Dec. 15	176	101	277	15	11	26	303
Dec. 16–Dec. 22	1,258	716	1,974	112	27	139	2,113
Dec. 23–Dec. 29	2,644	1,724	4,368	121	112	233	4,601
Dec. 30–Jan. 5	2,242	1,536	3,778	75	30	105	3,883
Jan. 6–Jan. 12	835	534	1,369	34	18	52	1,421
Jan. 13–Jan. 19	1,902	1,547	3,449	54	93	147	3,596
Jan. 20–Jan. 26	2,095	1,956	4,051	29	87	116	4,167
Jan. 27–Feb. 2	1,765	1,555	3,320	65	98	163	3,483
Feb. 3–Feb. 9	2,140	1,896	4,036	18	85	103	4,139
Feb. 10–Feb. 16	1,478	1,493	2,971	19	43	62	3,033
Feb. 17–Feb. 23	2,058	1,987	4,045	58	85	143	4,188
Feb. 24–Mar. 2	3,812	6,348	10,160	38	142	180	10,340
Mar. 3–Mar. 9	2,261	3,257	5,518	40	37	77	5,595
Mar. 10–Mar. 16	1,617	2,285	3,902	2	5	7	3,909
Mar. 17–Mar. 23	637	1,100	1,737				1,737
Mar. 24–Mar. 30	757	1,456	2,213				2,213
Mar. 31–Apr. 6	1,025	1,964	2,989				2,989
Apr. 7–Apr. 13	717	1,059	1,776				1,776
Apr. 14–Apr. 20	291	441	732				732
Apr. 21–Apr. 27	255	348	603				603
Apr. 28–May 4	36	70	106				106
Total	30,184	33,509	63,693	680	873	1,553	65,246

peak of the season was reached during the period February 24 through March 2, when 1,285 fishermen boated 10,340 shad.

Estimated Sport Catch, 1953-57

Estimates of the sport-fishery catch for the years 1953–57 are based on data collected in each of these years and on results of the 1958 study. The 1953–57 data were from one of the major sport camps and included the number of shad boats rented and the number of shad caught each day. From the 1958 survey we found that 27 percent of all the boats fished were rented from this camp. Assuming that the same percentage of all the boats fished was rented from this camp each year, an estimate of the number of boats fished each season (1953–57) was calculated (table 7).

To obtain an estimate of the sport-fishery catch each year, 1953–57, the average catch per boat, as determined from the selected sport camp, was multiplied by the estimated number of boats fished each year (table 7). It has been assumed that fishing success (average catch per boat) each year at the selected fish camp was similar to that of the entire sport fishery. This assumption appears justified, since the 1958 study revealed that the average boat caught 10.9 shad a day while those fished from the selected fish camp caught 11.0.

TABLE 7.—*Sport fishery for shad, St. Johns River, 1953–58*

[See text for determination of values]

Year	Sample data			Estimated total		
	Number of boats	Number of fish taken	Average catch per boat	Number of boats	Number of fish taken	Pounds of fish taken
1953	961	8,360	8.7	3,600	31,000	82,000
1954	726	7,559	10.4	2,700	28,000	74,000
1955	912	9,000	9.9	3,400	34,000	90,000
1956	699	6,522	9.3	2,600	24,000	64,000
1957	1,320	14,269	10.8	4,900	53,000	140,000
1958			10.9	6,000	65,000	175,000

The average weight by sex of the shad taken in the sport fishery in 1958 was determined from measurements of 230 males and 198 females. Males averaged 2.1 pounds, and females averaged 3.2 pounds. The sport fishery in 1958 took 30,864 male shad and 34,382 female shad (table 6). Converting this catch to a weight basis, 175,000 pounds were taken in 1958. The ratio of males to females in the catch was not known for years previous to 1958, and therefore it was assumed to be approximately equal. To convert the 1953–57 sport catch from numbers to pounds, the catches for these years were multiplied by a factor of 2.65, which was the mean weight of a sample of shad composed of equal numbers of each sex in 1958 (table 7).

SPAWNING ESCAPEMENT AND ANNUAL FISHING MORTALITY RATE, 1953–58

Shad which are not taken by the sport fishery are free to spawn and therefore comprise the spawning escapement. To determine the size of the spawning escapement for each year, 1953–58, the total commercial and sport catch was subtracted from the size of run in the same year. The annual fishing-mortality rate was determined by dividing total catch (commercial catch plus sport-fishing take) by size of the run (table 8).

TABLE 8.—*Annual fishing-mortality rate, shad fisheries, St. Johns River, Florida, 1953–58*

[In thousands of pounds]

Year	Size of run	Total catch [1]	Spawning escapement	Annual fishing-mortality rate (percent)
1953	989	362	627	37
1954	1,532	417	1,115	27
1955	2,681	524	2,157	20
1956	2,010	357	1,653	18
1957	2,717	401	2,316	15
1958	2,917	727	2,190	25

[1] Combined commercial and sport fisheries.

LIFE HISTORY OF SHAD

TIME OF RUN

As pointed out previously, shad enter the St. Johns River as early as November and the run lasts until March. Good catches are made at the river mouth during December and February, with the peak catch in the month of January. The relation between time of run and water temperature has long been recognized. Stevenson (1899), quoting from McDonald, discusses this relationship. He stated that shad did not enter the St. Johns River until the water cooled below that of the nearby ocean. This migration began about the last of November when the river temperature at Jacksonville dropped to 60° F. He further stated that shad did not enter other Atlantic coast streams until the temperatures in the rivers warmed above that of the adjacent ocean waters.

The mean monthly temperature of the St. Johns River at Mayport during the period

November through March, 1944 through 1954, ranged from 55° to 72° F. In some years the mean temperature does not reach 60° F., as occurred in the winter of 1949–50 when it ranged from 61° to 66° F. (U.S. Coast and Geodetic Survey, 1955). These data show that shad probably enter the St. Johns over a range of temperatures and do not necessarily delay their entry until the river water cools to 60° F. as reported by Stevenson. This agrees generally with Leach (1925), who stated that shad ascend rivers to spawn when the water temperature is from 56° to 66° F. By way of comparison, Talbot (1954) found that the peak of the run entered the Hudson River at temperatures ranging from 45° to 57° F., which are considerably lower than those found in the St. Johns River.

The mean monthly water temperatures in the river and ocean off the mouth of the St. Johns and Hudson Rivers for the years 1947 to 1954 are shown in table 9. These years are the only ones in which comparable data are available for these stations. From the table it can be seen that temperatures in the St. Johns River at Mayport average colder than in the ocean October through December but warmer during the remainder of the year. The early portion of the run enters when the river temperature is colder than that of the ocean; however, the majority of the run enters in January, February, and March, when the river temperature averages warmer than the ocean. Shad enter the Hudson River during the months of April and May when the river temperature is colder than the ocean (table 9). Thus it appears that shad will enter the St. Johns River at temperatures above 60° F. For this shad population, at least, some factor other than a temperature differential between river and ocean stimulates them to enter the river. This is evident, since during the early part of the run the temperature of the water in the river is colder than that of the ocean and during the remainder of the run warmer than that of the ocean.

TABLE 9.—*Mean monthly water temperatures in °F., in river and in ocean off mouths of St. Johns and Hudson Rivers, 1947 to 1954*

[Asterisks indicate months in which river temperatures are colder than ocean temperatures. Data St. Johns Lightship from Bumpus (1957); Mayport, Fla., New York City, and Sandy Hook, N.J., from U.S. Coast and Geodetic Survey (1955)]

Month	St. Johns River		Hudson River	
	River [1]	Ocean [2]	River [3]	Ocean [4]
January	59.8	58.6	39.0	37.4
February	59.7	58.7	37.2	36.4
March	63.1	61.4	* 39.7	40.4
April	68.8	67.1	* 47.2	49.3
May	75.8	73.9	* 55.7	57.9
June	81.2	79.3	* 65.2	68.2
July	82.6	80.6	* 72.1	75.3
August	82.5	80.8	* 73.4	74.8
September	81.3	80.9	70.8	70.0
October	* 74.8	75.0	63.1	60.8
November	* 66.1	68.1	53.5	49.9
December	* 60.0	60.4	44.5	40.6

[1] Mayport, Fla.
[2] St. Johns Lightship—off river mouth.
[3] New York City at the Battery.
[4] Sandy Hook, N.J.

AGE AND GROWTH

Collection and Examination of Material

During 1958, scale samples were collected over the entire season from fish captured by all types of fishing gear. These samples were considered representative of all size classes of shad taken by the fishery. Anchor gill nets and drift gill nets have a large mesh and therefore select the larger fish (mostly females). Haul seines are considered nonselective since their mesh size is small. The sport fishery is also nonselective; however, fishermen prefer female shad. The number of scale samples collected by fishing gear and sex of the fish for which ages were determined are shown in table 10.

TABLE 10.—*Number of shad aged, by sex and type of gear, St. Johns River, Florida, 1958*

Gear and sex	Number
Anchor gill:	
Female	483
Male	51
Drift gill:	
Female	434
Male	163
Haul seine:	
Female	572
Male	581
Hook and line:	
Female	476
Male	369
Total	3,129

Fork length to the nearest tenth of an inch, weight in ounces, and sex were determined for each fish from which scales were obtained. For consistency, all scales were taken from the left side of the fish, at about one-half the body depth and below the origin of the dorsal fin. In this area, shad scales are most symmetrical and therefore more accurately aged and measured for growth determinations.

Shad scales are not tightly imbedded and therefore are easily lost. Lost scales are replaced with scales of a regenerative type that do not show

all the growth rings. In the laboratory, each scale sample was examined before it was mounted and regenerative-type scales were discarded. Plastic impressions were made of two scales from each fish. The method used to age shad scales is described by Cating (1953), in which transverse-groove counts are used as an aid to determine location of annuli. Each fish was aged by two readers working independently and using an Eberbach projector. Scales for which age readings were in disagreement were re-read, and in most cases agreement was reached. Approximately 3 percent of the scales were discarded as unreadable. The validity of annuli as true year-marks on shad scales has been established by LaPointe (1958). In the present study the edge of the scale was termed an annulus since the fish were captured on their spawning run. Studies at the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C., indicate that the annulus is laid down on the shad scale during the late winter and early spring months. The positions of the focus and of the annuli on each scale were marked on strips of paper. A nomograph (Carlander and Smith, 1944) was then used to determine the fork length of the fish at time of annulus formation.

Body-Scale Relation

The body-scale relation was determined from a sample of 242 adult shad ranging in fork length from 12.8 to 18.8 inches. Fish were selected by 0.1-inch size classes by sex, and when available three fish were chosen as being representative of each size group. The body-scale relation was found to be similar for both sexes, and therefore the data were grouped, sexes combined, into 0.5-inch size classes as shown in table 11. The relation between fork length and scale radius was found to be highly correlated ($r=0.99$). The body-scale relation over the range of the data was linear. The regression equation obtained for fitting a straight line to the means of anterior scale radii and fork lengths was—

$$L=1.550S-0.156$$

where L=fork length in inches and S=anterior scale radius (inches$\times$26.7). The relation between average fork lengths and average scale radius is shown graphically in figure 3. Leim (1924) working on fish from the Shubenacadie

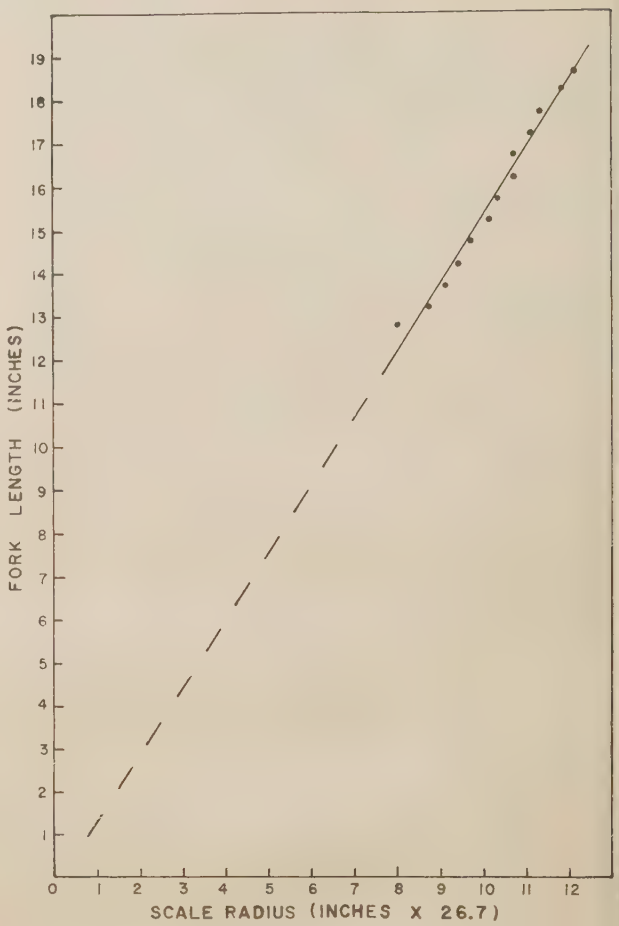

FIGURE 3.—Body-scale relation in shad of the St. Johns River.

River in Nova Scotia has shown that the length of shad at time of scale formation is approximately 27 mm. (1.1 in.). The intercept of the regression line (−0.2 in.) in figure 3 does not cross the axis of fish length at the time of scale formation. From this it is apparent that

TABLE 11.—*Relation of scale radius ($\times$26.7) to fork length in shad, sexes combined, St. Johns River, Florida*

[In inches]

Fork length	Number of fish	Average fork length	Average scale radius
12.5–12.9	1	12.8	8.0
13.0–13.4	10	13.2	8.7
13.5–13.9	17	13.7	9.1
14.0–14.4	17	14.2	9.4
14.5–14.9	19	14.7	9.7
15.0–15.4	25	15.2	10.1
15.5–15.9	30	15.7	10.3
16.0–16.4	30	16.2	10.7
16.5–16.9	30	16.7	10.7
17.0–17.4	24	17.2	11.1
17.5–17.9	15	17.7	11.3
18.0–18.4	15	18.2	11.9
18.5–18.9	9	18.6	12.1

these observations on adults cannot be extrapolated to show the body-scale relation in young shad. LaPointe (1958), working with data from both juveniles and adults, used a curvilinear regression line to describe the body-scale relation in shad from three rivers.

Age and Spawning-Class Distribution

The age-class distribution of 3,129 shad sampled from the commercial and sport fisheries is shown in table 12. All shad were on their initial spawning run. The majority of both males and females were 4 years old; however, a larger percentage of females than males were 5 years of age and older. In a similar study on the Hudson River, Talbot (1954) also found that shad spawned for the first time predominately at 4 to 5 years of age; however, as can be seen in table 13, St. Johns River fish mature and spawn at an earlier average age. Unpublished scale data collected in other years on these rivers are in agreement with this finding.

TABLE 12.—*Age-class distribution of shad, by sex, St. Johns River, Florida, 1958*

Age class	Male		Female	
	Number	Percent	Number	Percent
II	1	+		
III	129	11	8	+
IV	887	76	1,365	70
V	140	12	544	28
VI	7	1	46	2
VII			2	+
Total	1,164	100	1,965	100

+ Less than 0.5 percent.

TABLE 13.—*Age distribution at first spawning of shad from St. Johns River in 1958 and Hudson River in 1950 and 1951*

[Sexes combined. Hudson River data from Talbot (1954)]

Age class	St. Johns (percent)	Hudson (percent)
II	+	+
III	4	6
IV	72	47
V	22	36
VI	2	10
Over VI	+	1

+ Less than 0.5 percent.

Not any of the scales collected from shad of the St. Johns River in 1958 contained spawning marks. These are scarlike rings formed on the scales each year that the shad spawns (Cating 1953). This was also true for 730 samples collected in 1953 and 228 collected in 1950 by B. O. Freeman of the Florida Game and Fresh Water Fish Commission. These findings indicate that St. Johns River shad die after they spawn. Since shad generally sink after death, a mass mortality may not be obvious; however, persons frequenting the area of the spawning grounds in April and May have reported that weak and dying shad were being consumed by large numbers of white pelicans.

Additional evidence that these fish do not survive spawning was found in the 1953 tagging studies on the river. Approximately 600 tagged shad were not recovered in the fishery that year and therefore would be free to spawn. If they survived they could return to the sea and the following year re-enter the river to spawn. The fishery was canvassed after the 1954 fishing season, but not one of these tags was recovered. The fishery was also investigated after the 1959 season, but no shad tagged in 1958 was recovered, a further indication that these fish do not survive spawning.

Previous studies have shown that shad native to other streams south of Cape Hatteras also die after spawning (Sykes 1956; Walburg 1956, 1957). In contrast, shad that have spawned the previous year make up to 27 percent of the commercial catch in Chesapeake Bay (Walburg and Sykes, 1957) and up to 50 percent of the commercial catch in the Hudson and Connecticut Rivers (Talbot 1954; Moss 1946).

Growth of Shad

The sample of 242 fish used to determine the body–scale relation was also used to study average growth rate of St. Johns River shad (table 14). At any given age, the females were consistently larger than the males, and this difference in average length tended to increase with age.

Since shad enter this river over a prolonged period (November to March), a study was made to determine if any significant difference in the past year's growth increment occurred between fish of the same age entering the river early and those entering late in the run. This comparison revealed only small differences of less than 0.1 inch. From this we can conclude that annual growth was either essentially complete before the first shad entered the river or that those shad which entered late in the run continued their growth in the ocean and at the time of entrance into the river had attained a growth similar to that of the early arrivals.

TABLE 14.—*Growth rate of shad, by age class and sex, St. Johns River, Florida, 1958*

[Lengths in inches: M=male; F=female]

Age class	Number of fish	Sex	Fork length at capture	Calculated fork length corresponding to annulus number						
				1	2	3	4	5	6	7
III	37	M	13.7	6.8	11.3	13.7	----	----	----	----
III	5	F	14.3	7.0	11.6	14.3	----	----	----	----
IV	60	M	15.3	6.8	11.5	13.7	15.3	----	----	----
IV	66	F	16.2	7.0	12.0	14.3	16.2	----	----	----
V	26	M	16.7	6.8	11.4	13.6	15.4	16.7	----	----
V	37	F	17.7	7.1	11.7	14.1	16.2	17.7	----	----
VI	2	M	17.2	6.4	10.6	12.6	14.4	16.2	17.2	----
VI	7	F	18.2	7.1	11.1	13.2	15.2	16.9	18.2	----
VII	2	F	18.4	6.9	11.0	12.8	14.4	16.0	17.4	18.4
Total and weighted average length	125	M	-------	6.8	11.4	13.7	15.3	16.7	17.2	----
	117	F	-------	7.0	11.8	14.1	16.1	17.5	18.0	18.4
Length increment	-------	M	-------	6.8	4.6	2.3	1.6	1.4	0.5	----
	-------	F	-------	7.0	4.8	2.3	2.0	1.4	0.5	0.4

Length samples obtained from the haul-seine fishery indicate that the early run was generally made up of fish that averaged larger than those making up the remainder of the run (table 15). This was true not only for length but also for weight.

From the 3,129 fish sampled in this study, it was determined that the average fork length of males was 15.6 inches (range 12.0–17.6) and of females 16.8 inches (range 15.1–19.1). The average weight was 2.2 pounds (range 1.0–3.8) for males and 3.1 pounds for females (range 1.8–5.0).

TABLE 15.—*Average fork length of shad captured by haul seine, by sex and month, St. Johns River, Florida, 1958*

[In inches]

	Male		Female	
	Number	Average fork length	Number	Average fork length
December	132	15.7	109	17.2
January	194	15.1	195	16.8
February	175	15.0	159	16.7
March	90	15.2	115	16.8
Mean length (weighted)	----------	15.2	----------	16.8

FECUNDITY

The ova production of St. Johns River shad was determined from 19 ovary samples obtained during the period February 19 through March 11, 1958. To ensure that only unspawned females were selected, the samples were taken from the haul-seine fishery, approximately 90 miles downstream from the spawning area. The paired ovaries from each shad sampled were removed, wrapped in gauze, and preserved in 10-percent formalin. The fish ranged in fork length from 13.9 to 18.1 inches and in weight from 21 to 65 ounces. Age readings indicated that the fish were from 4 to 6 years of age.

The wet-weight method was used to determine the number of eggs in ovaries as described by Lehman (1953). In the present study, however, sample aliquots were taken only from the center portion of each ovary. The validity of this method of sampling to estimate ova production of shad was demonstrated by Davis (1957).

This study indicated that ova production ranged from 277,000 to 659,000 eggs (table 16). The relation between ova production and weight of the fish is shown in figure 4. A least square regression line fitted to these data is described by the formula—

$$Y=8.084X+65.405,$$

where Y = ova production and X = fish weight in ounces. The relation of these variables is linear ($r=0.90$). A direct relation between increase in egg production and increase in age or fork length is also evident from inspection of table 16.

Lehman (1953) found that ova production of Hudson River shad ranged from 116,000 to 468,000 eggs. The fecundity of St. Johns River shad is therefore greater despite the fact that fish from the Hudson average older and larger than those from Florida.

SPAWNING GROUNDS

A study to locate the spawning grounds in the St. Johns River was made during the 1953 investigation. Twenty-eight sampling stations were established between the south end of Lake George

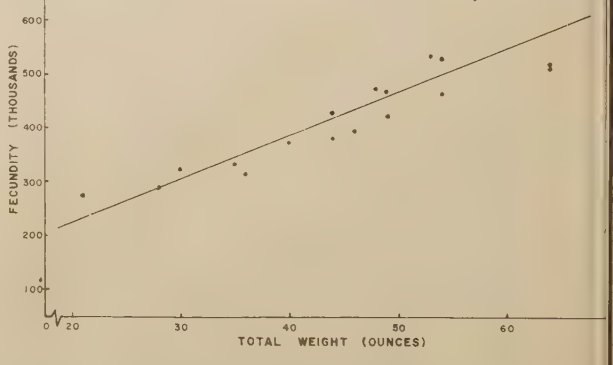

FIGURE 4.—Relation between number of ova produced and total weight of 19 shad, St. Johns River, 1958.

TABLE 16.—*Estimated ova production of 19 female shad, St. Johns River, Florida, 1958*

Date of capture	Fork length (inches)	Total weight (ounces)	Age (years)	Weight of ovaries (grams)	Mean number of ova per gram	Estimated number of ova (thousands)
Mar. 5	13.9	28	4	101.86	2,856	291
11	14.4	30	4	159.70	2,026	324
1	14.5	21	4	96.42	2,868	277
1	14.9	35	4	158.17	2,107	333
5	15.4	36	4	144.30	2,186	315
4	15.4	40	4	216.61	1,727	374
7	15.8	44	4	147.25	2,901	427
Feb. 27	15.9	46	5	148.82	2,662	396
25	16.4	44	4	197.06	1,938	382
27	16.4	48	4	195.52	2,432	476
21	16.8	49	4	213.38	2,204	470
Mar. 1	16.8	54	4	276.74	1,678	464
Feb. 19	16.9	53	5	221.10	2,434	538
Mar. 1	17.0	49	5	176.79	2,386	422
1	17.2	57	5	257.32	2,502	644
Feb. 19	17.5	64	6	274.82	1,894	521
25	17.7	54	5	222.49	2,394	533
25	18.0	64	5	234.72	2,210	519
21	18.1	65	6	288.90	2,281	659

and the source of the river near Melbourne, Fla., a distance of approximately 115 miles. The survey was begun in mid-February when the first spawned-out shad were observed in the Sanford area and continued until the middle of April when spawning was essentially complete. Cone-shaped nets made of fine-meshed nylon, with a diameter of 1 meter and a length of 3 meters, were used to obtain samples of eggs by anchoring them to the river bottom so that the current swept through them. For a more detailed description of this net and how it is fished see Massmann (1952).

Analysis of the data obtained from egg-net sampling revealed that the spawning area extended from Crows Bluff west of De Land to approximately 10 miles south of Lake Harney. The largest number of eggs was found in the area between the south end of Lake Monroe and the highway bridge immediately south of Lake Harney. In both 1953 and 1958 the shad spawning season extended from the latter part of February until the middle of April. The water temperature at the outlet of Lake Monroe during these months ranged from 60° to 75° F.[4]

DISCUSSION

Scientific management of the shad population of the St. Johns River to obtain optimum yields is not now possible because the factors that affect size of the run are unknown. A number of elements could have an effect on the population by either increasing or decreasing its size. Some examples are fishing, pollution, water temperature, streamflow, predation, and competition. Since the magnitude of the population is known for only 6 years, no conclusions can be made as to causes for fluctuations in abundance. After population parameters have been determined for an additional number of years, hypotheses may be formulated to account for changes in abundance. If factors affecting these changes can be determined and controlled, the shad population can then be managed on an optimum sustained yield basis. However, if the factors cannot be controlled, their effect could probably be predicted and the fishery managed accordingly.

[4] Water temperatures obtained from Florida Light and Power Company, Sanford, Fla.

SUMMARY

The shad fishery of the St. Johns River in Florida was studied during the winters of 1953 and 1958 as part of a coastwise investigation of the American shad begun by the Fish and Wildlife Service in 1950. The purpose of the present study was to obtain catch and effort data from the commercial and sport fisheries, fishing mortality rate, size of run, and basic life history information.

Shad fishing on the St. Johns River is conducted in widely separated and relatively short stretches of river. Anchor gill nets are fished at the mouth of the river, drift gill nets are fished in the vicinity of Jacksonville and Palatka, haul seines are fished between Welaka and Palatka, and a sport fishery is operated in the Sanford area.

Commercial shad fishing began in 1858. According to available records, the peak catch was made in 1908 when 2,833,000 pounds were landed. Since 1918, the catch has fluctuated between 203,000 and 964,000 pounds.

Since 1953, effort data have been obtained from the haul-seine fishery, and catch data have been obtained from both the commercial and sport fisheries. From a tagging study and analysis of catch and effort data, it was calculated that 2,709,000 pounds of shad were available to the haul-seine fishery in 1958. In this same year, gill nets caught 208,000 pounds of shad. Adding this catch to the number of pounds of shad available to the haul seines, the estimated size of the 1958 run was 2,917,000 pounds. With the basic population data obtained in 1958 and the catch and effort data collected since 1953, population size was determined for each year 1953 to 1957.

After shad pass through the commercial fishing area, they are subject to capture by the sport

fishery which operates between Lake Monroe and Lake Harney. During the 1958 study, a creel census was conducted on this fishery to determine fishing effort and size of catch. Partial data on this fishery were obtained each year since 1953. This information, together with that obtained in 1958, was used to obtain an estimate of the sport catch for each year 1953 to 1957.

Shad that escape the sport fishery are free to spawn and therefore comprise the spawning escapement. This escapement was determined for each year by subtracting both the commercial and sport catch from size of run.

Scale samples and length and weight data were obtained from 3,129 shad taken by all types of gear fished in the river. Age readings revealed that the majority of both males and females were 4 years old; however, a larger percentage of females were 5 years of age and older. Since scale readings indicated that all fish were spawning for the first time and since tagged fish were not recovered the year after tagging, it appears that St. Johns River shad die after their initial spawning run.

At any given age the females were larger than the males, and this difference tends to increase with age. The average fork length of males was 15.6 inches and that of females 16.8 inches. The average weight of males was 2.2 pounds and that of females 3.1 pounds.

Ova production ranged from 277,000 to 659,000 eggs, and there was a direct relation between egg production and age, length, and weight of the fish. Studies revealed that the spawning area extended from Crows Bluff west of De Land to approximately 10 miles south of Lake Harney. The spawning season extended from the latter part of February to the middle of April, during which time the water temperature ranged from 60° to 75° F.

Management of the shad population of the St. Johns River on an optimum sustained yield basis is not now possible because the factors that affect size of run are unknown. When population parameters have been determined for an additional series of years, studies can proceed to determine factors affecting population abundance.

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